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THE INSTALLATION SHALL BE MADE BY QUALIFIED INSTALLATION PERSONNEL AND SHOULD CONFORM TO ALL NATIONAL AND LOCAL CODES

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Hi5a Controller Function Manual

Arc Sensing (V40.21-00~)

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1 Overview

1.1. Before function description

This function is an optional function not included in the standard component and requires a License Key to execute the function.

1.2. Welding line tracking by arc sensing

Welding line tracking by arc sensing is carried out to track the welding line by detecting the change of welding current in the arc welding system including weaving. Arc sensing may take time to reach the correct welding line if there is an error in the start point. Thus using it in combination with touch sensing is recommended to detect the start point.

1.3. Condition to use arc sensing function

(1) Must be arc welding with weaving function

(2) If the digital arc welding machine transfers the current and voltage values, arc sensing may be available with the data from the welding machine. Some models of high-end welders provide data for the arc sensing function, in addition to the current, making it possible for arc sensing to be performed by using the data. (Please contact our engineer for more details.)

(3) If it is impossible to execute arc sensing with the data from the welding machine, a device is required to detect the welding current. The device can be installed inside the welding machine or configured as a separate box. With the touch sensing unit, its current and voltage sensors can be used. Otherwise, the system should be configured with the following two types of current detector and similar ones.

- CT(Current Transducer): LF-505S(www.lem.com)
  100[Ω](2W), 150[Ω](2W), ±24[V] SMPS
  2[mm^2] X 4[m] x 5 line
- Hole sensor : HC-U200V4B15(www.kohshin-ele.com)
  ±15[V] SMPS
  2[mm^2] X 4[m] x 5 line

1.4. System configuration

(1) To receive the analog voltage input with the controller

- With the touch sensing unit

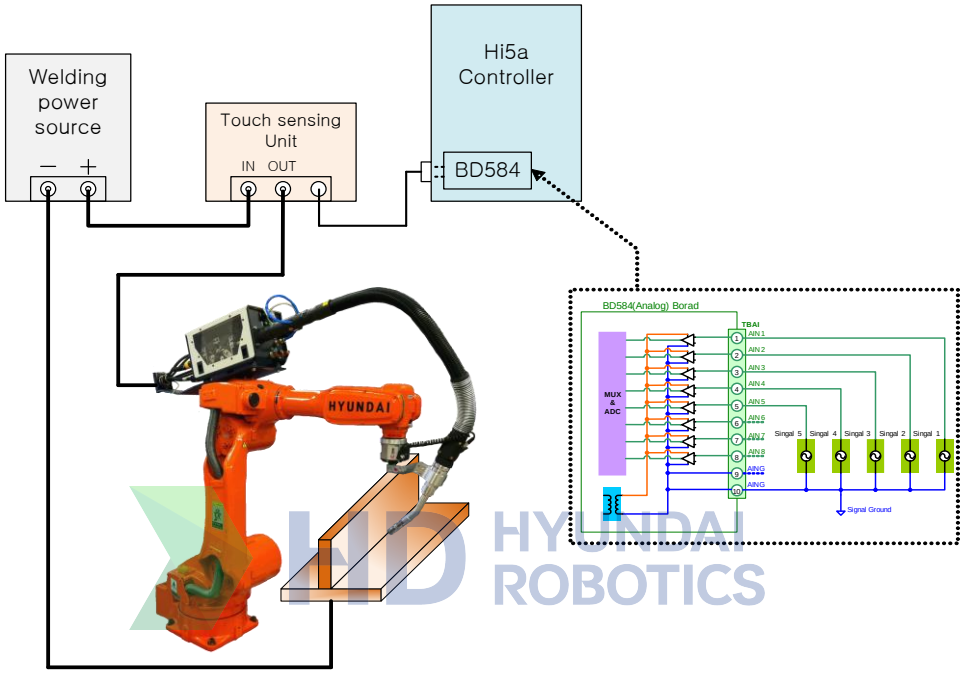

Figure 1.1 Configuration diagram for the case of using the touch sensing unit

- With other current sensors

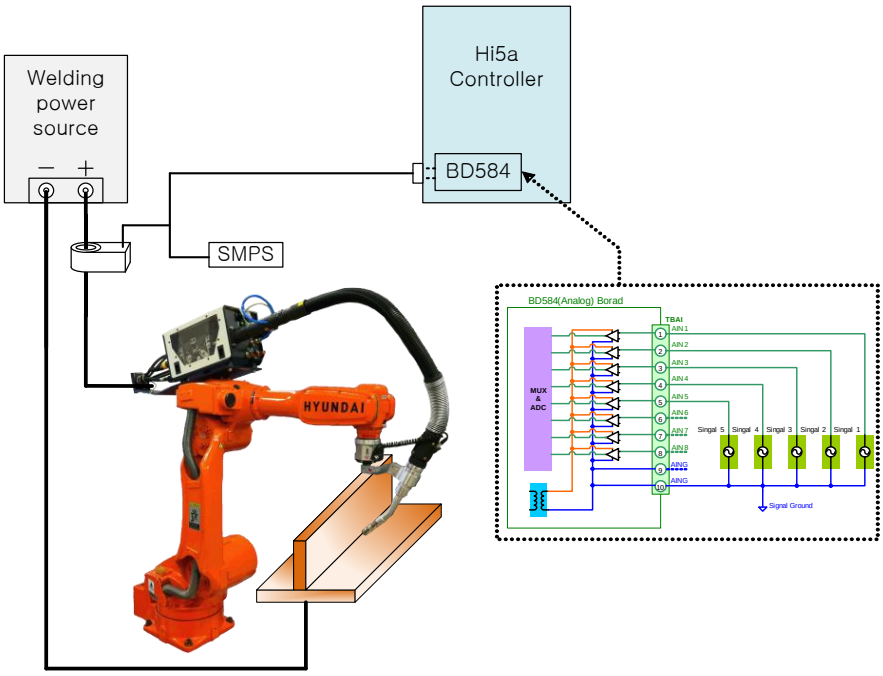

Figure 1.2 Configuration diagram for the case of using other types of current sensors

(2) To receive the analog voltage input with the fieldbus using the digital module

- With the touch sensing unit

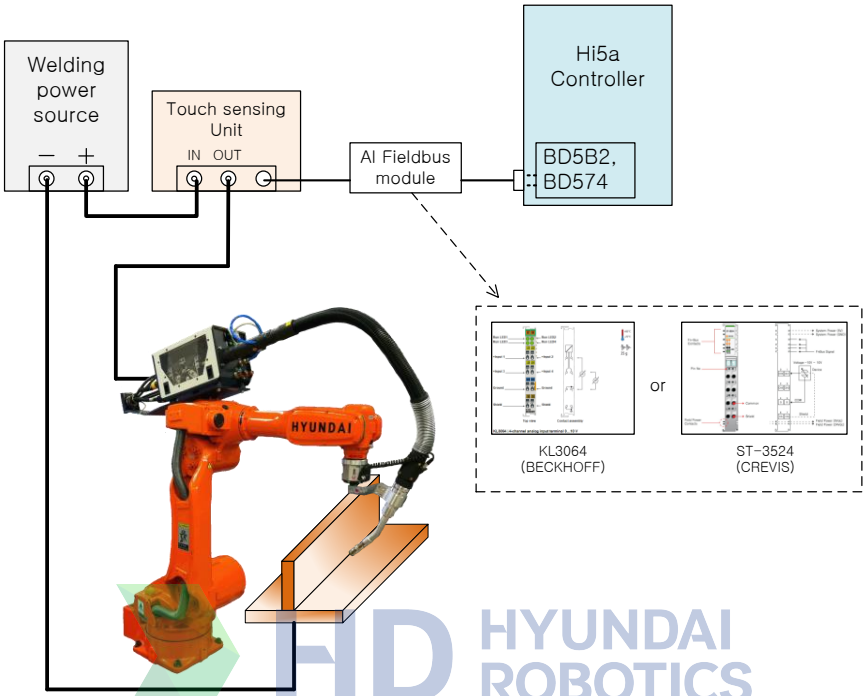

Figure 1.3 Configuration diagram for the case of using the touch sensing unit and fieldbus AI input module

- With other current sensors

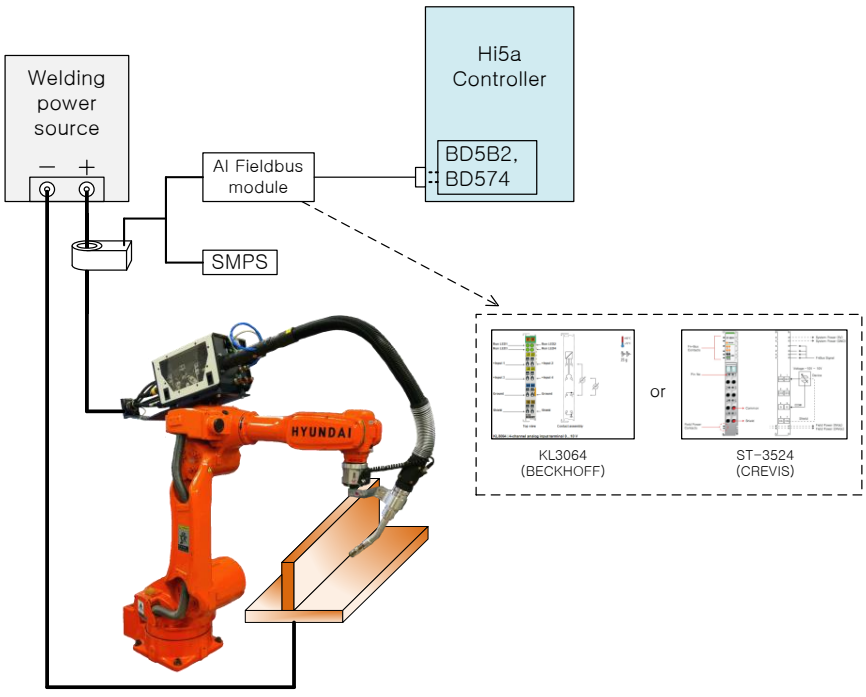

Figure 1.4 Configuration diagram for the case of using other types of current sensors and fieldbus AI input module

(3) To use the welding data directly for arc sensing

- Where a separate sensor does not have to be connected

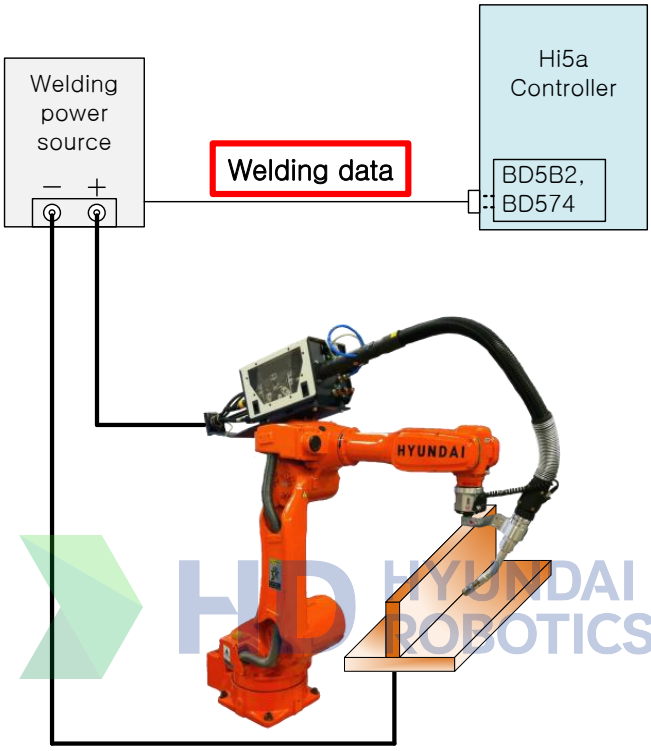

Figure 1.5 Configuration diagram for the case of using the welder data directly

1.5. Principle of arc sensing

In case of weaving during arc sensing, the distance between the torch and base material exists and the resistance changes as much as the distance to change the current. That is, the welding line can be followed by calculating the distance to both ends with the current change in the weaving section, and thus, the distance can be corrected in both directions on the weaving surface. In addition, the welding start point has a few errors in the up/down direction by touch sensing, so the up/down direction can be corrected by comparing the average current value of the weaving section center based on this value. If additionally adjusting the height during arc sensing is required, the up/down direction can be corrected based on the direct current input instead of the average one.

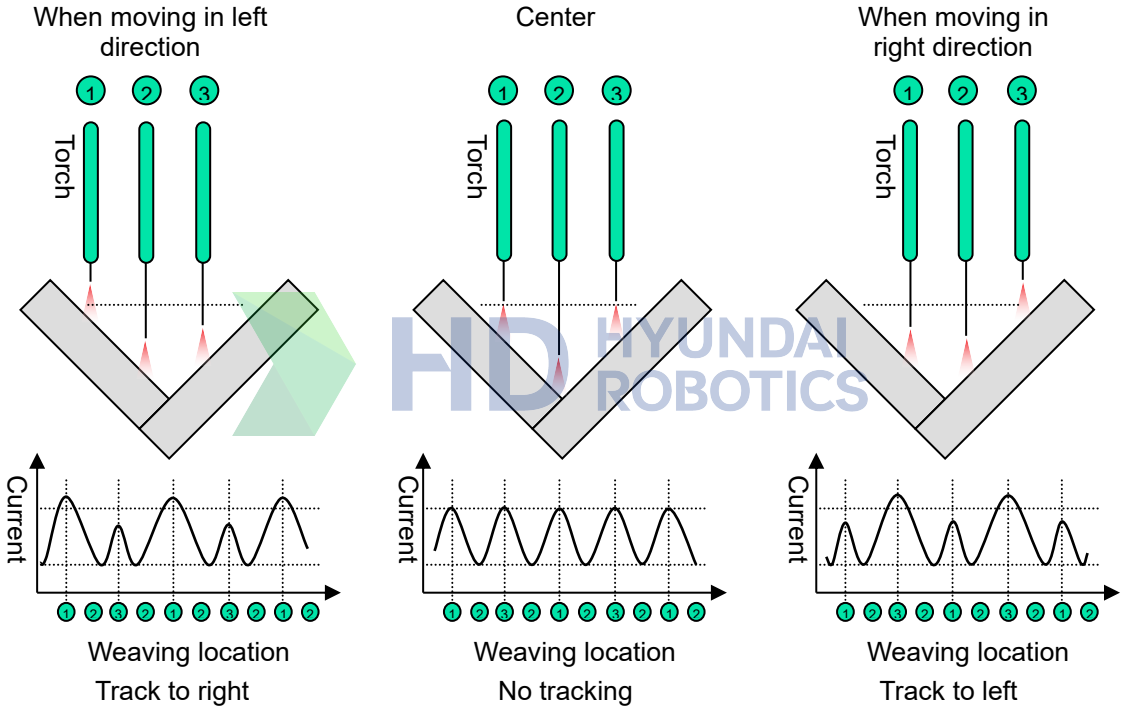

Figure 1.6 Relationship between the torch position and the current during arc sensing

1.6. Welding line tracking flow

The process of tracking the welding line by arc sensing is done as follows.

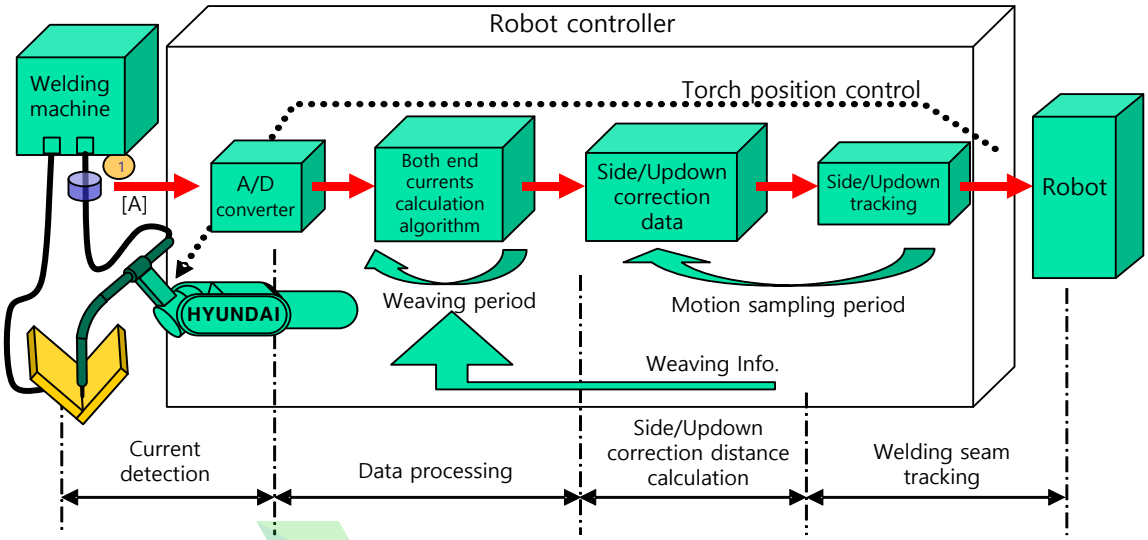

Figure 1.7 Arc sensing process

1.7. Arc sensor support specification

Because the welding line tracking function by arc sensing is the function that requires technical support of Hyundai Robotics Co.,LTD, all applied functions of the welding cannot be supported without the technical support of Hyundai Robotics Co.,LTD. The following specification shows the data based on sufficient testing by Hyundai Robotics Co.,LTD. Conditions other than the following specification must be communicated to Hyundai Robotics Co.,LTD. and requires testing for actual material and using condition.

(1) Welding condition

- Welding method : CO2, MAG, MIG, FCAW
- Applied wire thickness: 1.0 ~ 1.6φ (Solid wire, Flux cored wire)
- Maximum welding speed : Depends on welder characteristics
- Applied welding current : 160[A] ~ 600[A]

(2) Workpiece condition

- Minimum thickness : 2t or above
- Maximum tracking performance :
- The maximum correction distance per second can be determined by the left/right sensing sensitivity.
- A validation test is required as the welding trajectory can oscillate if the tracking performance is increased.

(3) Weaving condition

- Frequency range : 0.5 ~ 4.0 Hz
- Amplitude range : 2.0 X 2.0 mm or above
- Weaving form : Simple harmonic oscillation
- Dwell time : 0.0[sec] ~ 2.0[sec]

(4) Interpolation type

- Linear interpolation : Possible
- Arc interpolation : Possible
- Positioner synchronized linear : Possible
- Positioner synchronized arc : Possible

(5) Joint type

- Fillet, V-groove
- Maximum permitted gap : Differs by weaving width

(6) Other function

- Sensing trace deviation limit function
- Torch height setting during sensing

2

Basic Setting

2.1. Introduction

Items to be set to use the arc sensing function are as follows.

- Input data setting for arc welding sensing
- Weaving and Arc sensing condition setting
- Weaving and Arc sensing condition setting with commands

2.2. Input data setting for arc welding sensing

Analog and digital inputs as well as welding data can be used to detect the arc welding current. Each of them requires different settings.

(1) Select 『[F2]: System』 → 『4: Application parameter』 → 『2: Arc welding』 from manual mode.

(2) Item No. 13 of the arc application menu, the “Data input setting for sensing: [Enable, Disable]” can be set. With the “Valid” setting, press “[F1]: Input signal setting” to display the following screen, to set the input signals for arc welding sensing.

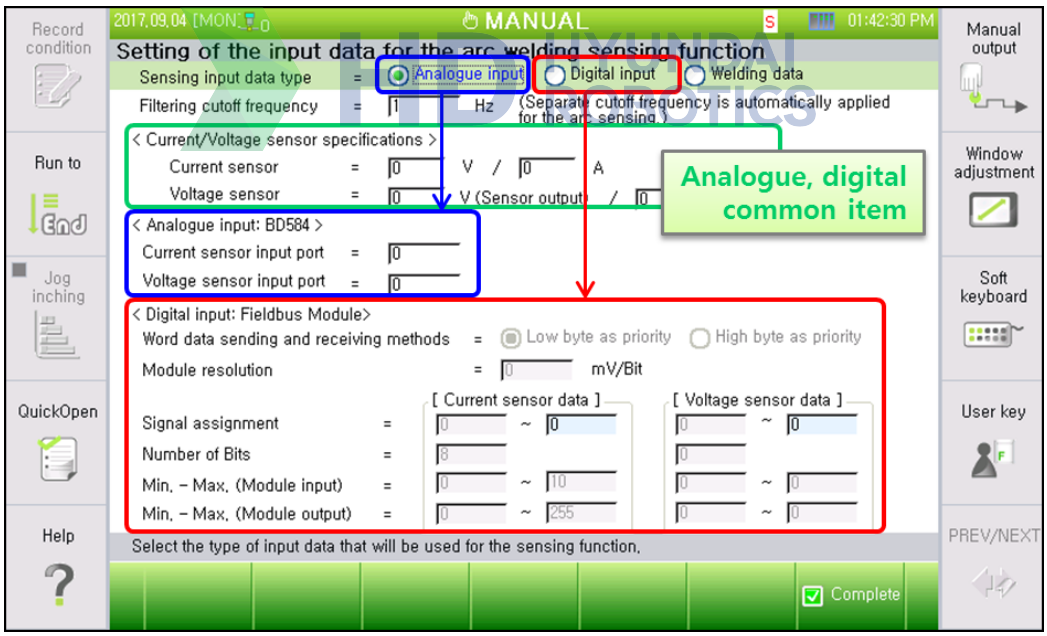

Figure 2.1 Setting of the input data for arc welding sensing

(3) Select the type of sensing data to enable any item to set.

(4) With regard to sensor data filtering, it is required to set the filtering level that is to be applied to the input signal for arc sensing. When the welder sends a signal that is filtered for arc sensing, the sensing response speed will be made quicker if “No filter” or “Partial filtering” is set. If you are using a typical welder or current/voltage sensor, maximum filtering can be used..

(5) Current/voltage sensor specifications are common for analog and digital inputs. Set them according to the specifications of the sensor that will be used.

(6) If the analog voltage needs to be entered directly through the controller BD584 board, select "Analog input" and select the current/voltage sensor input port.

(7) If it is required to receive the analog voltage as a fieldbus signal using the fieldbus module for analog voltage input, select “Digital input.” Input data into the enabled items according to the module hardware specifications and communication node setting

(8) If a digital communication welding machine is used and the data refresh rate is fast, arc sensing can be performed with the data from the welding machine. In this case, select “Welding data.”

2.3. Weaving and Arc sensing condition setting

(1) Weaving condition

Because arc sensing basically includes the weaving, it is included in the weaving condition file. The weaving condition file is displayed in the following screen when you locate the cursor on the {WEAVON WEV#=?} command and press the [QuickOpen] key.

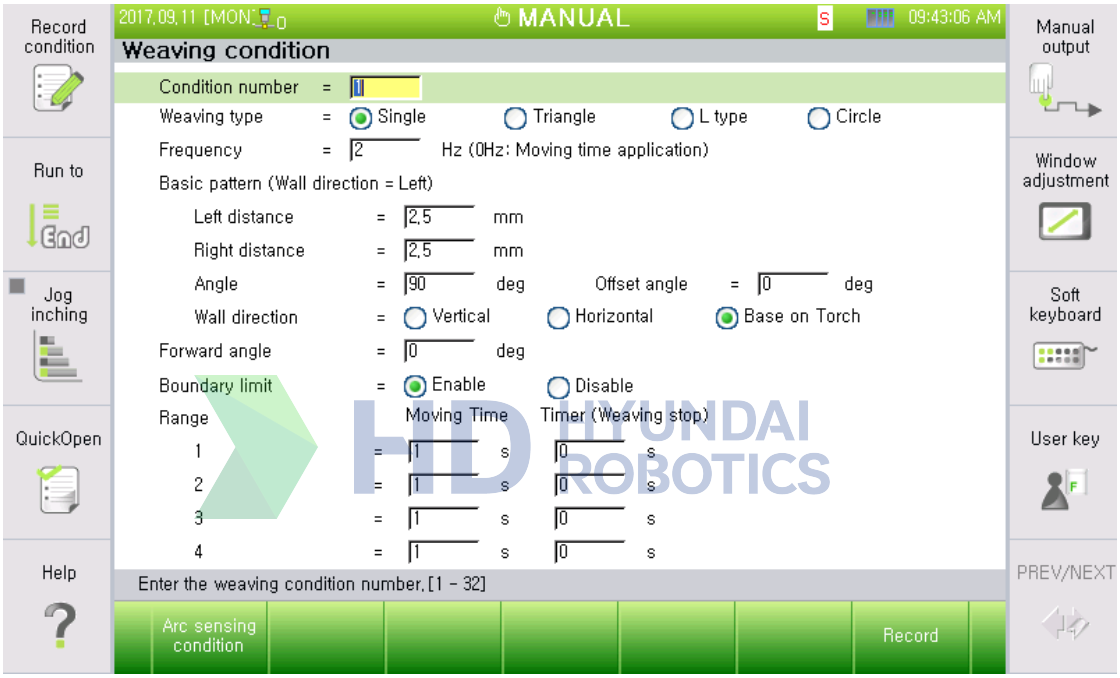

Figure 2.2 Weaving condition setting

- Condition number: [1] (Range: 1–32)
  The weaving condition number is currently under editing.

- Weaving type: 〈Simple harmonic motion, triangle, L type, and circular〉
  Designate the type of weaving.

- Frequency: [2] In Hertz (Range: 0.0–10.0)
  Set the weaving frequency. The range is 0.0–10.0 Hz. If the frequency is set to “0,” apply the moving time.

- Basic pattern
  Set the pattern of weaving.

  - Wall direction distance: [2.5] (Range: 0.5–50.0 mm)
    Left leg length viewed from the weaving proceeding direction
  - Opposite direction distance: [2.5] (Range: 0.5–50.0 mm)

Right leg length viewed from the weaving proceeding direction

- Angle: [90°] (Range: 0.1° –180.0°)
  Designate the angles of the wall and opposite-direction weaving surfaces.
- Wall direction: 〈Vertical direction, horizontal direction, and torch standard〉
  Designate what reference is to be used to set the direction of the wall. The default is the “Torch posture as reference.”
- Offset angle: [0°] (Range: –90.0° to 90.0°)
  If the wall direction is based on the “Torch standard,” designate the angle to shift in the middle of the weaving surface.

- Forward angle: [0°] (Range: –90.0° to 90.0°)
  Weaving angle direction for the proceeding direction. If it is “0,” the forward and weaving directions are perpendicular. Set the angle of inclination if diagonal weaving is needed.

- Boundary limit: 〈Enable, Disable〉
  Set if the weaving trajectory is limited by the boundary of the welding start and end points. If it is enabled, the weaving trajectory is limited within the welding section.

- Moving Time: [1] (Range: 0.01–10.0 s); Timer: [0] (Range: 0.00–2.00)
  If the weaving frequency is set to “0,” weaving is performed with the moving time. Set the moving time for sections and the weaving stop time between them.

(2) Arc Sensing Condition - User

After "[F1]: Arc sensing condition" in the weaving condition dialog box is pressed, the following "Arc sensing condition – User" dialog box is displayed.

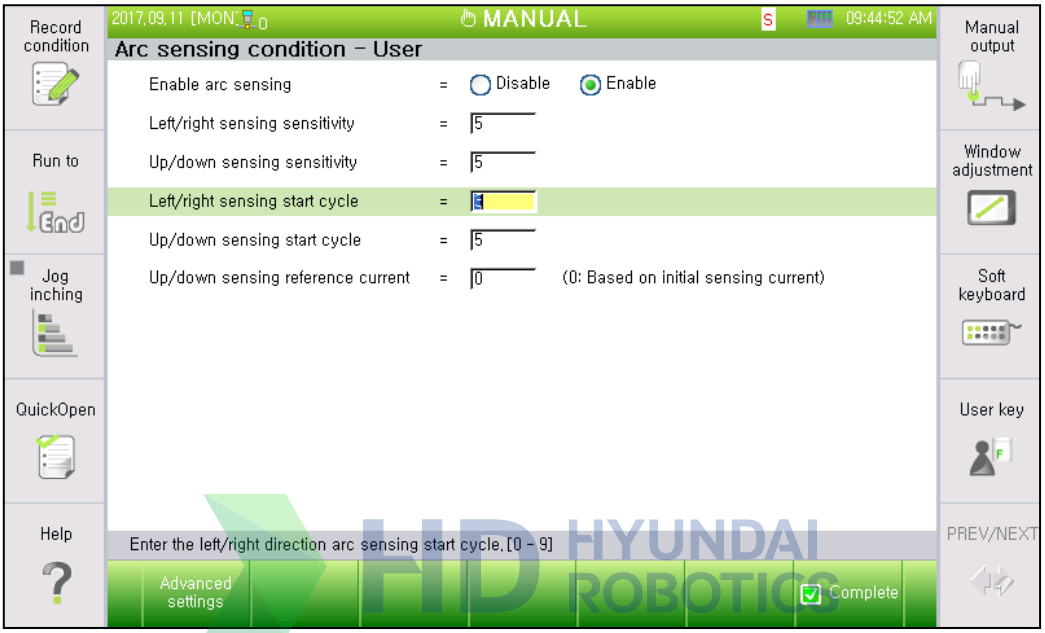

Figure 2.3 Arc sensing condition – User setting

- Enable arc sensing: 〈Enable, Disable〉
  Set to enable or disable arc sensing.

- Left/right side sensing sensitivity: [0–10]
  Set the left/right sensing sensitivity on the weaving surface. If it is set to "10," it follows the entire maximum correction distance per second set by the engineer. If it is set to "0," it is not followed to the left/right side.

- Up/down sensing sensitivity: [0–10]
  Set the up/down sensing sensitivity on the weaving surface. If it is set to "10," it follows the entire maximum correction distance per second set by the engineer. If it is set to "0," it is not followed to the up/down side.

- Left/Right side sensing start cycle: [0~9]
  Set the weaving cycle to start tracking with the left/right side sensing. It is desirable to skip two to three cycles as the welding current is unstable upon starting arc welding.

- Height sensing start cycle: [4~10]
  Set the weaving cycle to start tracking with the up/down sensing. Set the cycle after starting the left/right side sensing as the reference current needs to be set for the up/down sensing.

- Up/down sensing reference current: [0–3,000] A
  The reference current for up/down sensing: The current is decreased or increased if the projection of the wire is increased or decreased, respectively, for arc welding. Therefore, designate the reference current to adjust the torch height. If “0” is entered, select it based on the current value of the up/down sensing start cycle at the beginning of welding.

- Arc sensing type selection: 〈Welding line, Current difference, and Current difference + Gap〉
  Select the arch sensing following method.
  Welding line: Performs the welding line tracking by taking as reference the position where the current is the lowest. This should be used for the root pass welding that has no sealing bead and tack welding.
  Current difference: Performs the welding line following by comparing the current difference between both at the ends of the weaving. This can be used even when there is a root pass and a sealing bead. Basic option.
  Current difference + Gap: This option makes it possible to adjust the weaving width and weaving speed, together with performing the welding line following, by using the current difference between both ends of the weaving. This is to be used for the butt welding in which there is deviation among workpieces.

(3) Arc Sensing Condition - Engineer

After the "[F1]: Advanced setting" in the "Arc sensing condition – User" dialog box is pressed, the following "Arc sensing condition – Engineer" dialog box is displayed.
※ Engineer privilege is required to enter this dialog box.

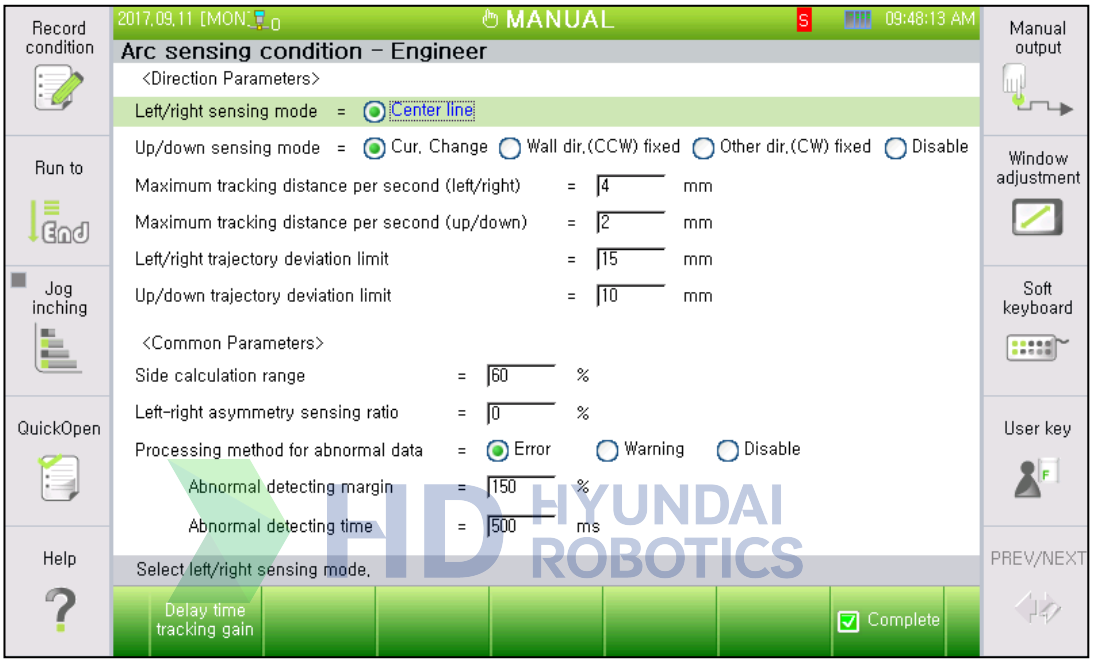

Figure 2.4 Arc sensing condition – Engineer setting

- Left/right side sensing mode: 〈Center line〉
  Select the left/right side sensing mode. The center line mode is supported for now.

- Up/down sensing mode: 〈Current change, Wall direction fixation, Opposite direction fixation, and Disable〉
  An item to select the up/down method: General arc sensing can correct the height with the current change, so the current change is mostly used. However, aluminum welding may not correct the height with the current change, so the height can be sensed if one side is fixed with the wall or opposite-direction fixation.
  If "Disable" is selected, only left/right side sensing is performed.

- Maximum correction distance per second (left/right): [0.1–20.0] mm
  Set the left/right side maximum track distance per second. The actual maximum track distance is calculated as follows.

  Actual maximum track distance (left/right) = Maximum correction distance per second (left/right) × left/right side sensing sensitivity / 10

- Maximum correction distance per second (up/down): [0.1~20.0] mm
  Set the up/down maximum track distance per second. The actual maximum track distance is calculated as follows.

  Actual maximum track distance (up/down) = Maximum correction distance per second (up/down) × up/down sensing sensitivity / 10

- Left/right trajectory escape limit: [0~200] mm
  Maximum left/right side distance that the robot can track from the teaching trajectory. The robot will stop if it is out of the teaching trajectory beyond this value. If the robot is out of trajectory, this function may be used to minimize the distance to weld an incorrect position.

- Up/down trajectory escape limit: [0~200] mm
  Maximum up/down distance that the robot can track from the teaching trajectory. The robot will stop if it is out of the teaching trajectory beyond this value. If the robot is out of trajectory, this function may be used to minimize the distance to weld an incorrect position.

- Side calculation range: [1~100]%
  Set the current range to compare the left/right side current values. Perform the sensing with the current value from the left/right vertex of weaving by this range.

- Asymmetrical left/right side sensing rate: [-40 to 40]
  Rate to track the welding line while forming the left/right side welding bead in an asymmetrical manner. Perform welding by shifting in the left (-) and right (+) directions within the entire weaving section according to the set rate.
  This rate is proportional to the weaving width and will work correctly if the welding line track gain is correctly set.
  If an excessive asymmetrical rate is set, the welding line may be avoided. In this case, reduce the asymmetrical rate.

- How to process abnormal data: 〈Error, warning, and disable〉
  This is the data processing method when the sensing input data is unstable during welding.
  - Error: E32756 (The arc sensing current exceeded the normal range by the abnormality judgement time.) The error occurs, and the robot stops.
  - Warning: W32756 (The arc sensing input data is unstable, so they exceeded the normal range by the abnormality judgement time.) The warning occurs, but the robot continues operation.
  - Disable: It continues sensing by ignoring the abnormal data.

- Abnormality judgment margin: [100~200]%
  This sets the margin to judge as abnormal current. Judgment of abnormal current is done based on the past 5 data points.
  Upper limit of abnormal judgment = Average of past 5 data points × Abnormal judgment margin,
  Lower limit of abnormal judgment = (Average of past 5 data points × 2)- Upper limit of abnormal judgment

- Abnormality judgment time: [10~1000]m/sec
  This sets the time to judge as abnormal when the input current exceeds the 『Abnormal judgment margin』. Although this value is an element used to decide how quickly the recognition of abnormal data can be judged, if this is set too low, a false error may be detected. Therefore, this must be set according to the environment.

- Trajectory deviation decrease: 〈Disable, Enable〉
  When the following based on the welding line is to be used and if the following direction calculated using the current difference between the left and right sides is different from the following direction calculated by considering the welding line, this menu makes it possible to select the handling method.
  Disable: Reflects the welding-line–based compensation amount into the compensation distance
  Enable: Handles the calculated compensation amount as 0 to maintain the existing compensation distance

- Maintaining the compensation distance during a step forward/backward: 〈Clear, Maintain〉
  If the step forward/backward operation is to be performed after stopping during arc sensing or during a multipass operation, this menu makes it possible to set whether to maintain the existing compensation distance.
  Clear: Sets the compensation distance as 0
  Maintain: Performs the step forward/backward operation while maintaining the compensation distance

(4) Data delay and following coefficient table

After the "[F1]: Delay time following coefficient" in the "Arc sensing condition – Enginer" dialog box is pressed, the following "Data delay and following coefficient table" dialog box is displayed.

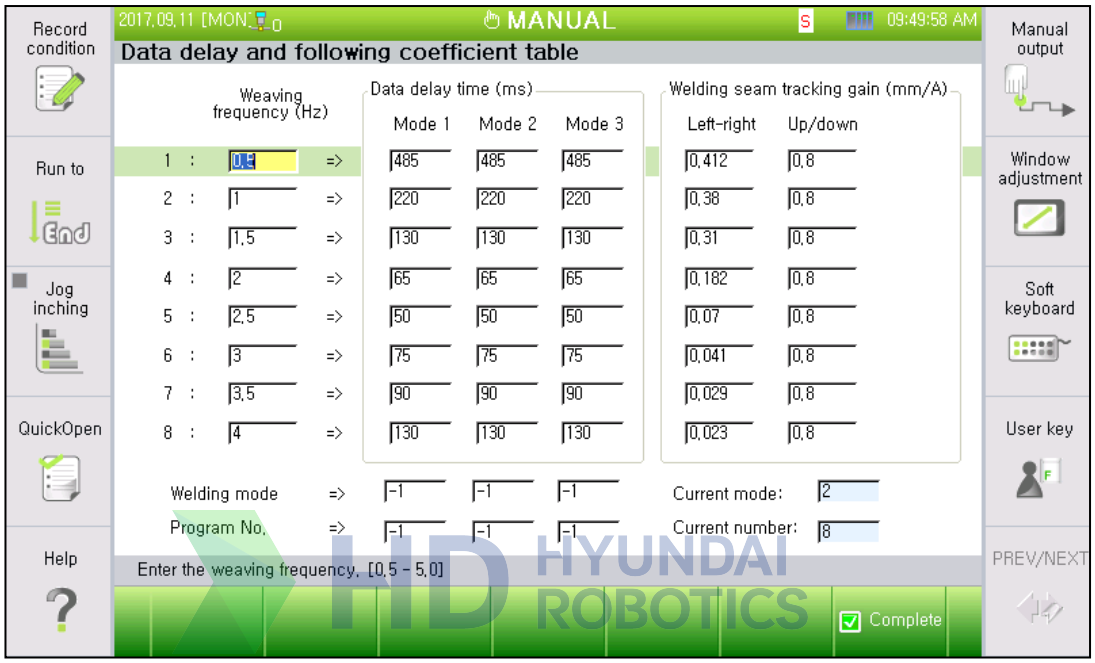

Figure 2.5 Data delay and following coefficient table setting

- Weaving frequency
  Enter the weaving frequency to enter the table data. In general, create the table from 0.5 to 4.0 Hz with an interval of 0.5 Hz.

- Data delay time
  Enter the data delay time for each weaving frequency. This delay time is calculated through a separate test (refer to 6.2). Up to three modes can be entered by the welding mode (pulse and gas type) or the program number of the welding machine. The data delay time is applied during sensing according to the welding mode or the program number.

- Welding line following gain
  Current value change gain according to torch position change for each weaving frequency: Left–right/up–down gains are separate and calculated through a separate test (refer to 6.2).

- Welding mode
  Enter the mode of the welding condition to be used for sensing. Enter a value in the data delay time mode to apply by the referencing current mode displayed on the side after welding.

- Program number
  Enter the program number of the welding machine to be used for sensing. Enter a value in the data delay time mode to apply by the referencing current number displayed on the side after welding.

※ If there is no mode that does not match with the welding mode or program number that is used for the current welding work, the delay time for the mode for which the welding mode is set as 0 and the program number set as 0 will be used as the default delay time. If the welder uses the job mode and many job numbers, sensing can be performed using this default delay time.

2.4. Weaving and arc sensing condition setting with commands

(1) Necessity of the function

Weaving and arc sensing conditions are included in the weaving condition file. The number of condition files is limited to 32, and the conditions may not be automatically changed during the operation. However, using more than 32 conditions or changing some of them automatically will be required.
In this case, commands may be used to change weaving and arc sensing conditions.
The changed conditions with this command are valid only in the corresponding weaving section.

(2) How to use commands

- In the manual mode, insert commands as follows.

  [Enter command] → [F7: Substitution] → [PREV/NEXT] → Insert WEAVCmd → Select a weaving parameter

- Commands are entered as follows.

  WEAVCmd.[Weaving parameter]=Value

  Example)
  WEAVON WEV#=1 → Weaving command statement
  WEAVCmd.PatVert=4 → Wall direction distance set with the command
  WEAVCmd.PatHori=3 → Opposite direction distance set with the command

  MOVE L,S=5mm/s,A=1,T=2 → MOVE statement
  …
  ..

- The input values of the commands are limited to the same ranges of condition settings of the condition files. However, StickOut and FdTrkClr elements are not the weaving and arc sensing conditions.

- Parameters that are not separately designated with commands use the conditions set with the WEAVON command.

- The following table shows whether the setting value is applied to the function of each element of WEAVCmd.

Variable name	Right after WEAVON command	Weaving operation without arc sensing	Weaving operation with arc sensing	Continuous change of welding conditions
Type	Apply	Apply	Apply	Apply
Freq	Apply	Apply	Apply	Apply
PatVert	Apply	Apply	Apply	Apply
PatHori	Apply	Apply	Apply	Apply
PatAngle	Apply	Apply	Apply	Apply
PatWalDi	Apply	Apply	Apply	Apply
OffsetAng	Apply	Apply	Apply	Apply
FwdAngle	Apply	Apply	Apply	Apply
BoundLmt	Apply	Apply	Apply	Apply
MoveTime	Apply	Apply	Apply	Apply
Dwell	Apply	Apply	Apply	Apply
HSMethod	Apply	Not apply	Apply	Apply
SideSens	Apply	Not apply	Apply	Apply
UpdnSens	Apply	Not apply	Apply	Apply
BaseCur	Apply	Not apply	Apply	Apply
StickOut	Apply	Not apply	Apply	Apply
AsymSsDist	Apply	Not apply	Apply	Apply
FdTrkClr	Apply	Not apply	Apply	Apply

(3) Weaving parameters and details

- Type: Weaving pattern
- Freq: Weaving frequency
- PatVert: Wall direction distance
- PatHori: Opposite direction distance
- PatAngle: Basic pattern angle
- PatWalDi: Wall direction of the basic pattern
- FwdAngle: Forward angle
- BoundLmt: Boundary limit use status
- MoveTime: Time of each section with moving time
- Dwell: Time to stop weaving only with moving time
- HSMethod: How to execute up/down sensing during arc sensing
- SideSens: Left/right side arc sensing sensitivity
- UpdnSens: Up/down arc sensing sensitivity
- BaseCur: Up/down sensing reference current

  By setting this value, you can set the distance between the torch and the base material. Decrease the value if you want to set a longer distance between them. Meanwhile, increase the value if you want to set them closer.

- StickOut : This value is to move the torch in the up and down directions during arc sensing. The torch height will be changed by the value entered in 'mm'. When a + value is entered, the distance between the torch and the base material increases, and when a – value is entered, the torch becomes closer to the base material.
- AsymSsDist : Asymmetrical left/right side sensing rate
- FdTrkClr : When this variable is set as 1, the compensation distance in the direction of the welding line during arc sensing will be gradually cleared during arc sensing that proceeds in a straight line. During an arc sensing operation in which the length is long and there are many curves, this function can be used in a case where the compensation distance acquired by sensing in the previous curved section should not be used for the sensing for the next curved section.

2.5. Arc sensing monitoring

(1) Monitoring execution

If you select '26: Arc sensing data' among monitoring items, arc sensing monitoring will be executed.
This item is activated only when the arc sensing license is valid.

(2) Description of the monitoring items

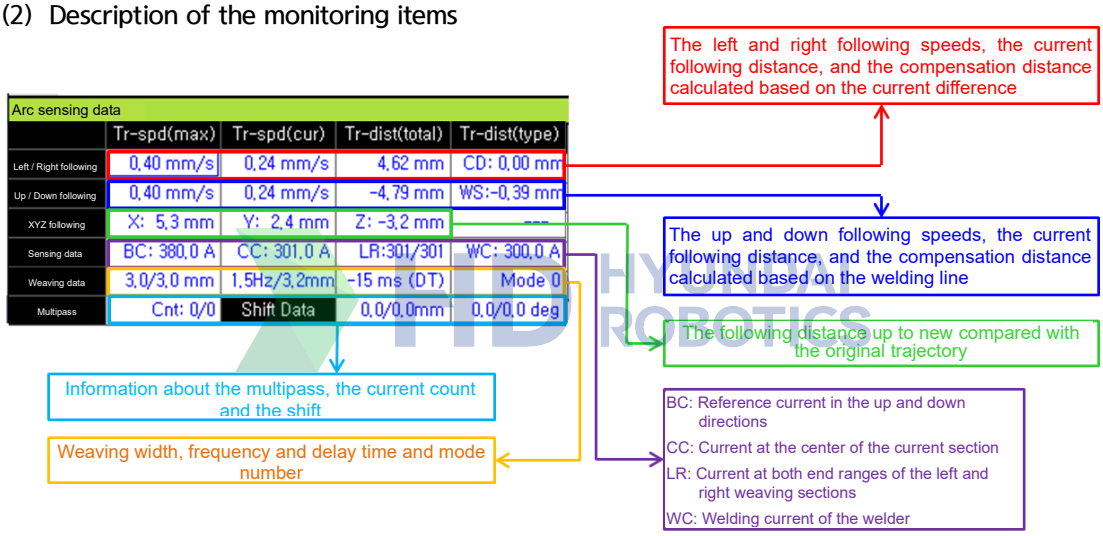

Figure 2.6 Detailed description of the arc sensing monitoring window

- Left / Right following: Indicates the following speed and distance through the sensing in the left and right directions as well as the left and right compensation distances calculated based on the current difference method

- Up / Down following: Indicates the following speed and distance through the sensing in the up and down directions as well as the left and right compensation distances calculated based the welding line method

- XYZ following: Indicates the distance followed up to now compared with the original trajectory, in the X, Y and Z directions of the base coordinates.

- Sensing data

  BC: The sensing reference current in the up and down directions
  CC: The current at the center of the current section for the sensing in the up and down directions

LR: Current at the end range of the current section
WC: Welding current of the welder
Mode: Delay time and mode number that are currently applied

The reference current in the up and down direction should be set as a value acquired by averaging the values of the current at the center, along a certain section, of the welding start range.
When it comes to the sensing in the up and down directions, the compensation distance in the up and down directions should be calculated based on the difference between the reference current and the measured current. When the reference current is increased, the torch and base material will get closer and, when the reference current is lowered, the torch and base material will get distant.

- Weaving data: Indicates the current weaving width, the weaving frequency, the delay time and the mode number.

- Multipass: Indicates the current / entire count of the stored multipass data as well as the shift distance and angle.

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3

Multipass Welding Function

3.1. Introduction

The multipass welding function can be used when a single operation of welding cannot be applied because the required leg length for the arc welding of thick plates is wide or when the welding needs to be repeated several times because the volume to be filled through welding is large.

Because of the characteristics of arc sensing, sensing may be unstable, except for the root pass, so the welding line following should be performed through arc sensing only in the case of the root pass. The following trajectory needs to be saved, and the saved trajectory needs to be shifted to create more than two passes for the welding work.
Because the position of the multipass work program just needs to be maintained along the same trajectory as that of the root pass, the multipass work can be performed simply by copying the root pass work program and then only inserting the multipass command.

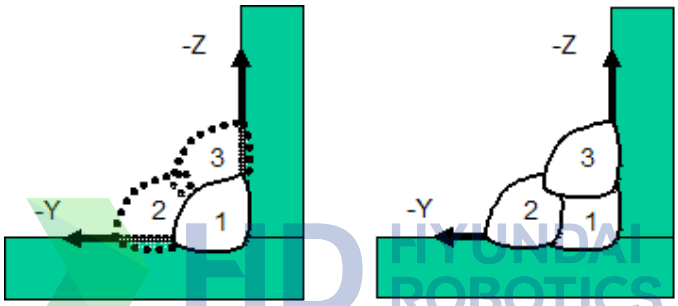

Figure 3.1 Multipass welding for the 2nd and 3rd passes after arc sensing (left) for the root pass

Figure 3.2 Actual multipass welding

When the multipass beads are created in an inclined laminated form as shown in Figure 3.2, welding can be performed in the laminated form as shown below if you modify the welding start and end points by recording them by pulling them slightly.

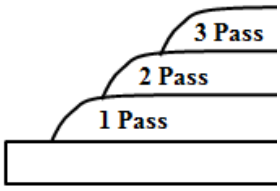

Figure 3.3 Inclined laminated multipass shape

3.2. Commands and Operation Principles of Multipass

(1) MULTIPASS command

You can save and load the sensing trajectory using the “MULTIPASS” command. This command is divided into the one for starting the saving of the trajectory and the other for ending the saving of the trajectory, based on the first parameter.

(2) Multipass trajectory saving

This MULTIPASS function makes it possible to record the count, position, and compensation amount at a designated trajectory number for a set distance during arc sensing. Multiple trajectory sets can be saved. When welding is performed alternatively for two or more welding sections to minimize the deformation of individual workpieces, various trajectory numbers can be used.

The command to start saving the data for multipass is as follows:

MULTPASS SAVE, TrjNo=[Trajectory number], SampDist=[Sampling distance]

- The trajectory number to save the compensation amount and position of the arc sensing [1-50]
- Sampling distance: This is the distance of the gap between the trajectories to be saved. [Default: 10.0 mm, Range: 5.0-100.0 mm]
- In general, save the trajectory using the default setting.
- Increase the gap if the welding section is long and exceeds the saved trajectory range.
- If there is severe bending of the welding section, set this distance short.

(3) Multipass trajectory playback

The commands for loading data and starting playback for multipass are as follows:

MULTPASS LOAD, TrjNo=[Trajectory number, Side=[Left/Right shift], Updown=[Up/Down shift], Reverse= [Playback direction], TAS=[TAS angle], WAS=[WAS angle]

- Trajectory number: Trajectory No. 1-50 to load
- Left/Right and Up/Down shift: The distance to shift from the original trajectory [Default: 0, Range: -20.0-20.0 mm]
- Playback direction: Set whether to play back the multipass in the right or reverse direction [0: right direction is the default, 1: reverse direction]
- Travel Angle Shift (TAS): Shift in which inclination occurs in the forward/backward direction [-20° -20°]
- Work Angle Shift (WAS): Shift in which the torch is inclined in the directions of both surfaces [-20° -20°]

(4) Multipass playback direction

In the case of an arc sensing multipass, the saved trajectory playback direction can be used in two ways. The playback direction should be determined and selected according to the field situation by taking into account the degree of deformation of the workpiece, the shape of the weld bead, the cycle time, etc.

- Right-direction multipass

  Next pass proceeding direction: Same as the direction of the saved trajectory for which the arc sensing is performed

  When it comes to the work program, the welding trajectory of the original root pass will be used.

- Reverse-direction multipass
  Next pass proceeding direction: Opposite the direction of the saved trajectory for which the arc sending is performed
  In the work program, the trajectory of the root pass welding is used by reversing the step sequence in the reverse order. In this case, it is required to check the trajectory as there could be confusion about the designation of the position.

(5) Left/Right and Up/Down shift
This function makes it possible to set the distance to shift from the original trajectory during playback. Because the torch weaving is perpendicular to the tool, each shift will be set, as seen below. In other words, the left and right directions will be the weaving surface, and the up and down directions will be the surface perpendicular to the weaving surface.

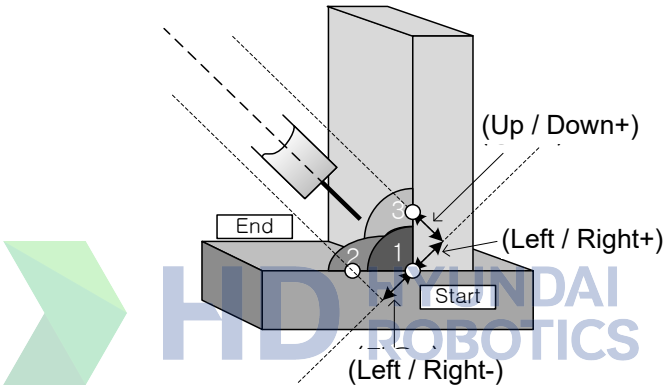

Figure 3.4 Concept of the multipass shift direction

(6) Angle shift: TAS, WAS
This needs to be set when the torch needs to be inclined to secure quality in performing multipass welding.
The concept of individual items is as shown below:

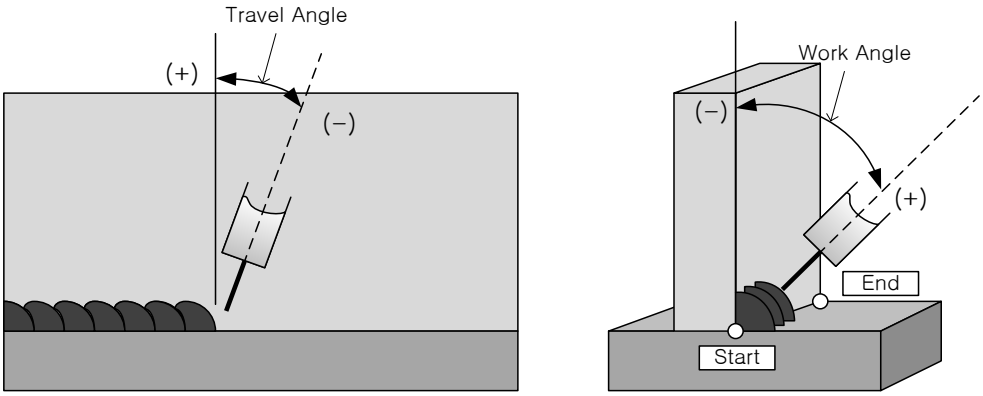

Figure 3.5 Concept of the multipass angle shift


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4
Work
Programming

4.1. Overview

Perform the following operation programming example for arc sensing.

- Fillet welding that uses touch sensing and arc sensing
- Arc sensing with weaving width auto setting through touch sensing
- Multipass welding that uses the function of saving the trajectory

4.2. Fillet welding that uses touch sensing and arc sensing

In general, the arc sensing function is used together with the touch sensing function. The touch sensing function enables you to find the exact welding start and end positions, and the arc sensing function allows you to find the correct direction by moving after the welding starts.

The first example is the most basic fillet welding.

The work sequence is as shown below:

1) Setting the weaving conditions, arc sensing conditions, and welding conditions
2) Searching the welding start position using touch sensing
3) Searching the welding end position using touch sensing after moving near the end position
4) Performing the work using the weaving commands and arc commands at the welding start position.

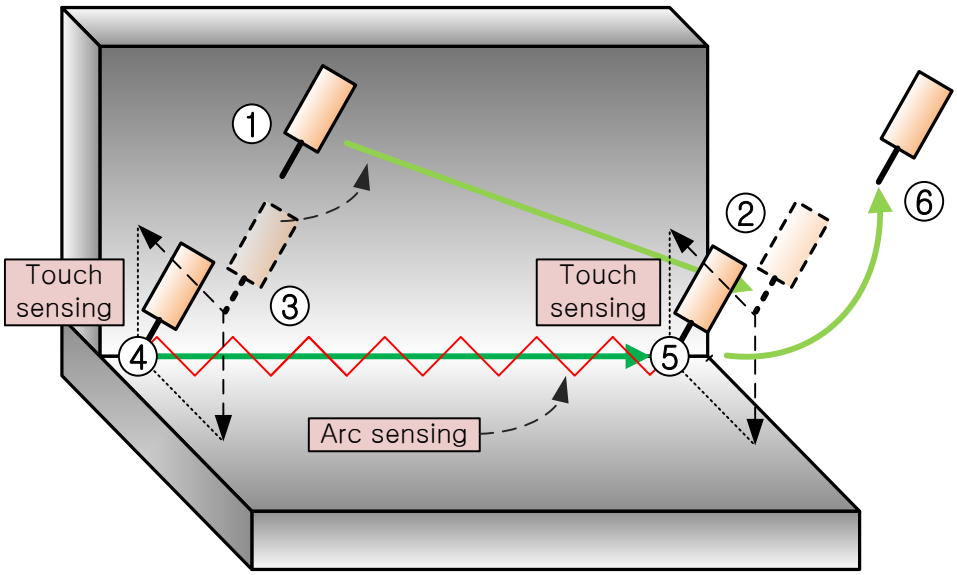

Figure 4.1 Fillet touch sending and arc sensing

- The example program is as follows:

```
~~~~~~~Arc sensing program : 0001.JOB~~~~~~~~~~~~~~~~
' Arc sensing program
S1    MOVE P,S=60%,A=3,T=1                    ' 1: Operation start point
S2    MOVE L,S=30%,A=3,T=1                    ' 2: End point touch sensing position
TOUCHSEN TSC#=1,-X,-Z,0,P10,V1!               ' 3: Save the end point touch sensing position at P10
S3    MOVE L,S=30%,A=3,T=1                    ' 4: Start point touch sensing position
      TOUCHSEN TSC#=1,-X,-Z,0,P1,V1!          ' 5: Save the start point touch sensing position at P1
S4    MOVE L,P1,S=20%,A=3,T=1                 ' 6: Move to the welding start point
      WEAVON WEV#=1                           ' 7: Start the weaving and arc sensing
      ARCON ASF#=1                            ' 8: Start the welding
S5    MOVE L,P10,S=60cm/min,A=3,T=1           ' 9: Move to the welding end point
      ARCOF ASF#                              '10: End the welding
      WEAVOF                                  '11: End the weaving and arc sensing
S6    MOVE P,S=60%,A=3,T=1                    '12: Operation end point
      END
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

4.3. Arc sensing with the weaving width auto setting through touch sensing

Create one work program that can be applied to both workpieces, as shown below:

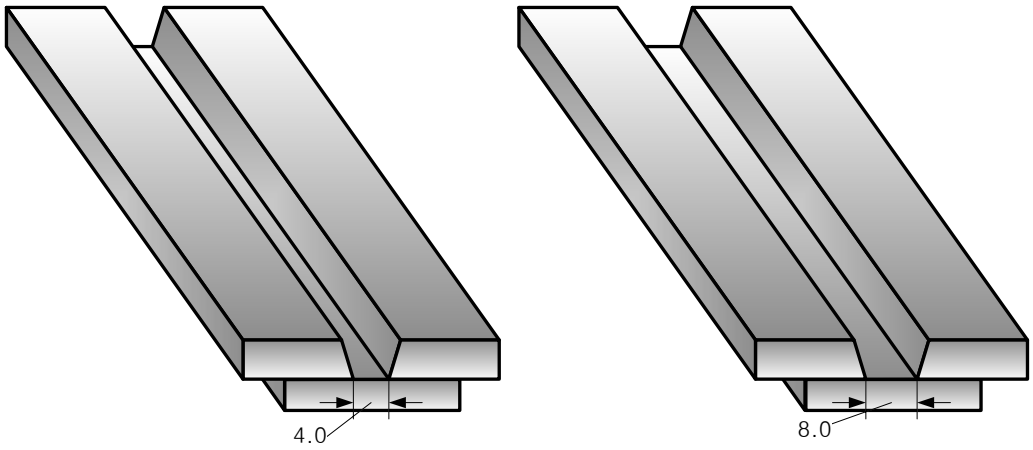

Figure 4.2 Workpiece for butt touch sensing and arc sensing

The work environment will be assumed as below:

Process of welding between two workpieces
180° flat weaving
The welding progress direction is X + direction. The touch sensing of the workpiece is performed left and right in the Y direction.
It is assumed that the setting of the arc sensing parameters has been completed.
In the case of a 4.0 mm gap, the welding speed is 7.0 mm/sec.
In the case of an 8.0 mm gap, the welding speed is 3.5 mm/sec

The work sequence is as below:

1) Measure the welding center position and gap distance at the butt part of the end point using the touch sensing command.
2) Measure the welding center position and gap distance at the butt part of the start point using the touch sensing command.
3) Determine if the V10! Value is within the allowable value. Stop when it exceeds the range of 2.0–10.0 mm.
4) Designate each half of the measured distance as the distance in the wall direction (left surface) and in the opposite direction (right surface), respectively.
5) Perform interpolation calculation using the welding speed of 4.0 mm/sec and 8.0 mm/sec. If the gap is less than 4.0 mm, apply a fixed speed of 7.0mm/sec, and if the gap exceeds 8.0 mm, apply a fixed speed of 4.0 mm/sec.
6) Progress the work through the automatic entering of the weaving width and welding progress speed using the calculated value.
7) Return to the original position after the work is completed.

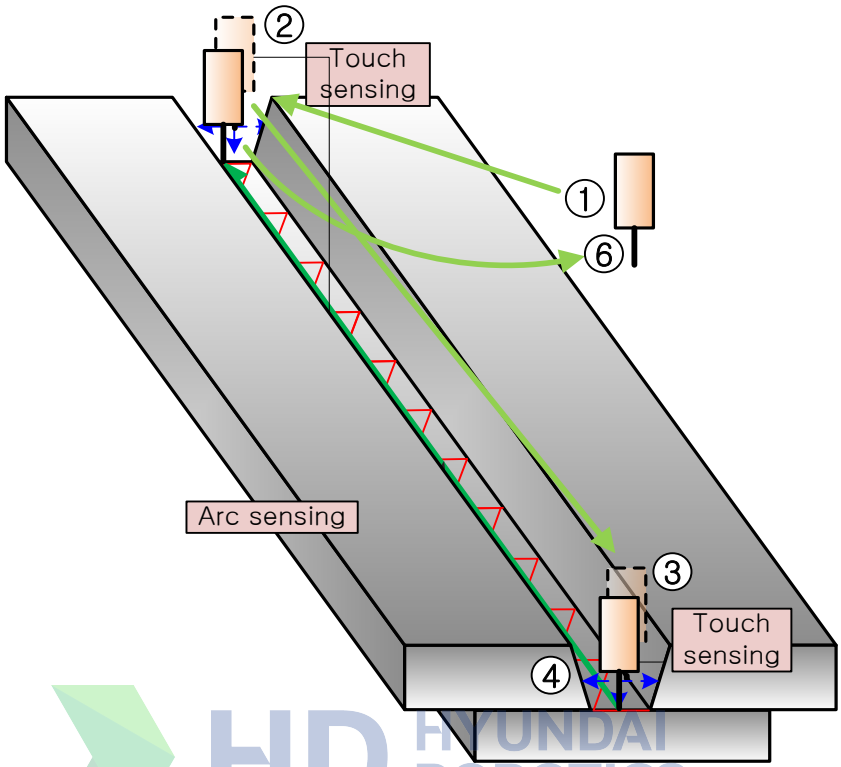

Figure 4.3 Butt touch sensing and arc sensing

- The example program is as follows:

```
~~~~~~~Arc sensing program : 0002.JOB~~~~~~~~~~~~~~~~
      'Butt Arc sensing program
      Digits in the units place: Start condition. , Digits in the tens place: End condition
S1    MOVE P,S=60%,A=3,T=1                          ' 1: Operation start point
S2    MOVE L,S=30%,A=3,T=1                          ' 2: End point touch sensing position
       TOUCHSEN TSC#=2,+TY,-TZ,5,P10,V11!       ' 3: Save the end point touch sensing position at P10
S3    MOVE L,S=30%,A=3,T=1                          ' 4: Start point touch sensing position
       TOUCHSEN TSC#=3,+TY,-TZ,5,P1,V1!         ' 5: Save the start point touch sensing position at P1
      'Calc. weld speed, width according to Gap V1!              Setting of the speed according to the gap
       IF V1!<2.0 OR V1!>10.0 THEN                   ' Exceeded the allowable range
       GOTO *Error
       ELSEIF V1!<4.0 THEN                      ' If the gap is less than 4.0 mm, fix the speed as 7.0
                                                  mm/sec
       V3!=7.0 'Weld speed at start
       ELSEIF V1!>8.0 THEN                      ' If the gap is more than 8.0 mm, fix the speed as 4.0
                                                  mm/sec
       V3!=4.0 'Weld speed at start
       ELSE                                  ' If the gap is within the range of 4.0-8.0 mm, calculate the
                                               speed through linear interpolation
       V3!=(7-3.5)/(4-8)*V1!+10.5            ' Linear interpolated weld speed at start
       ENDIF
       V4!=V1!/2.0 'left side width          ' Designate the half of the gap as the left-side weaving width
```

```
        V5!=V1!/2.0 'right side width          ' Designate the half of the gap as the right-side weaving width.
        '-------------------------------------------------------
        'Calc. weld speed, width according to Gap V11!
        IF V11!<2.0 OR V11!>10.0 THEN                    ' Exceeded the allowable range
        GOTO *Error
        ELSEIF V11!<4.0 THEN                    ' If the gap is less than 4.0 mm, fix the speed as 7.0
                                                mm/sec
        V13!=7.0 'Weld speed at start
        ELSEIF V11!>8.0 THEN                    ' If the gap is more than 8.0 mm, fix the speed as 4.0
                                                mm/sec
        V13!=4.0 'Weld speed at start
        ELSE                                    ' If the gap is within the range of 4.0-8.0 mm, calculate the
                                                speed through linear interpolation
        V13!=(7-3.5)/(4-8)*V11!+10.5            ' Linear interpolated weld speed at end
        ENDIF
        V14!=V11!/2.0 'left side width
        V15!=V11!/2.0 'right side width
        '-------------------------------------------------------
S4      MOVE L,P11,S=20%,A=3,T=1                ' 6: Move to the welding start point
        WEAVON WEV#=2                           ' 7: Start the weaving and arc sensing
        ARCON ASF#=2                            ' 8: Start the welding
        ARC_COND L,V3!,V4!,V5!,2,400,32         ' 9: Start of weld parameter continuous change
S5      MOVE L,P10,S=60cm/min,A=3,T=1           '10: Move to the welding end point
        ARC_COND L,V13!,V14!,V15!,2,400,32      '11: End of weld parameter continuous change
        ARCOF ASF#                              '12: End the welding
        WEAVOF                                  '13: End the weaving and arc sensing
S6      MOVE P,S=60%,A=3,T=1                    '14: Operation end point
        END
        *Error                                  '15: Position for retracting when the range of gap is
                                                exceeded
        DO200=1                                 '16: Signal output for indicating an error
        STOP                                    '17: Stop the robot
        END
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

4.4. Example of Multipass Welding

The work program can be written as below.
This work is about performing welding in a way that after the 1st pass welding is completed, the 2nd pass welding and 3rd pass welding are performed while being shifted 3.0 mm to the left and right at an elevated height of 3.0 mm.

```
        ‘~~~~~~~Multipass program : 0003.JOB~~~~~~~~~~~~~~~~
        'Cylinder AS and MP Program
S1      MOVE P,S=60%,A=3,T=1
        'Find 4 Points by touch sensing
S2      MOVE L,S=30%,A=3,T=1                    ' 1: Position of searching the first point on the circular
                                                trajectory
        TOUCHSEN TSC#=4,TF,TD,0,P1,V1!          ' 2: Touch sensing of the first position on the circular
                                                trajectory
S3      MOVE L,S=30%,A=3,T=1                    ' 3: Position of searching the second point on the
                                                circular trajectory
        TOUCHSEN TSC#=4,TF,TD,0,P2,V1!          ' 4: Touch sensing of the second position on the
                                                circular trajectory
S4      MOVE L,S=30%,A=3,T=1                    ' 5: Position of searching the third point on the circular
                                                trajectory
        TOUCHSEN TSC#=4,TF,TD,0,P3,V1!          ' 6: Touch sensing of the third position on the circular
                                                trajectory
S5      MOVE L,S=30%,A=3,T=1                    ' 7: Position of searching the fourth point on the circular
                                                trajectory
        TOUCHSEN TSC#=4,TF,TD,0,P4,V1!          ' 8: Touch sensing of the fourth position on the
                                                circular trajectory
        '1st pass                               Save the 1st multipass trajectory through arc sensing
S6      MOVE L,S=60%,A=3,T=1
S7      MOVE L,P1,S=50%,A=3,T=1
        WEAVON WEV#=3
        MULTIPASS SAVE,TrjNo=1,SampDist=10
        ARCON ASF#=3
S8      MOVE C,P2,S=60cm/min,A=3,T=1
S9      MOVE C,P3,S=60cm/min,A=3,T=1
S10     MOVE C,P4,S=60cm/min,A=3,T=1
S11     MOVE C,P1,S=60cm/min,A=3,T=1
        ARCOF ASF#
        WEAVOF
        MULTIPASS OFF
S12     MOVE P,S=60%,A=3,T=1
        '2nd pass                               Shift the 2nd pass 3 mm horizontally in the right direction and
                                                3 mm in the vertical direction
        MULTIPASS LOAD,TrjNo=1,Side=3,Updown=3,Reverse=0,TAS=0,WAS=0
S13     MOVE L,P1,S=20%,A=3,T=1
        WEAVON WEV#=4
        ARCON ASF#=3
S14     MOVE C,P2,S=60cm/min,A=3,T=1
S15     MOVE C,P3,S=60cm/min,A=3,T=1
S16     MOVE C,P4,S=60cm/min,A=3,T=1
S17     MOVE C,P1,S=60cm/min,A=3,T=1
```

```
        ARCOF ASF#
        WEAVOF
        MULTIPASS OFF
        '3rd pass                 Shift the 3rd pass -3 mm horizontally in the right direction and
                                  3 mm in the vertical direction
S18  MOVE P,S=60%,A=3,T=1
        MULTIPASS LOAD,TrjNo=1,Side=-3,Updown=3,Reverse=0,TAS=0,WAS=0
S19  MOVE L,P1,S=20%,A=3,T=1
        WEAVON WEV#=4
        ARCON ASF#=3
S20  MOVE C,P2,S=60cm/min,A=3,T=1
S21  MOVE C,P3,S=60cm/min,A=3,T=1
S22  MOVE C,P4,S=60cm/min,A=3,T=1
S23  MOVE C,P1,S=60cm/min,A=3,T=1
        ARCOF ASF#
        WEAVOF
        MULTIPASS OFF
S24  MOVE P,S=60%,A=3,T=1
        END
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

5 Error, Warning

5.1. Error

Code	E32752 “Use data input signal for sensing” is disabled.
Detail	The “Data input setting for sensing” of the arc application setting is disabled.
Action	Among the arc welding entries of application parameter, enable the “Data input setting for sensing.”

Code	E32753 “Sensing data type” is “Analog input” and the analog voltage input port is 0.
Detail	In the “Arc welding sensing input data setting,” sensing data type is set to analog input but the port is set to 0.
Action	Set the current sensor input port of the analog input to one where the sensor signal is input.

Code	E32754 “Sensing data type” is “Digital input,” and the current sensor digital signal input port is 0.
Detail	In the “Arc welding sensing input data setting” of the arc application setting, the sensing data type is set to digital input but the port no. 0 is set.
Action	Among the arc welding entries of the application parameter, set the digital input entry of the “Data input setting for sensing” according to the system.

Code	E32755 The detected initial sensing value is too low.
Detail	Arc sensing input data is too low to perform normal sensing.
Action	1) Check the state of the sensor and sensor signal line connection. 2) Check if the voltage detected with the sensor is within a good range using another equipment. 3) Check if the sensor port and range settings are correct.

Code	E32756 Arc sensing current exceeded the normal range above the abnormality determination time.
Detail	Arc sensing input data is unstable so it exceeded the normal range above the abnormality determination time.
Action	1) Check if the sensing data has been correctly inputted during welding. 2) If the sensing data is correct, set a large abnormality determination margin and time.

Code	E32757 Arc sensing error (exceeded left/right sensing range)
Detail	This error will be occurred when the calculated side tracking distance cannot be catched up for a certain cycle.
Action	Adjust the sensing sensitivity, maximum compensation distance per second, and welding line following gain.

Code	E32758 Arc sensing error (upper and lower sensing ranges exceeded)
Detail	This error will be occurred when the calculated height tracking distance cannot be catched up for a certain cycle.
Action	Adjust the sensing sensitivity, maximum compensation distance per second, and welding line following gain.

Code	E32759 Abnormal cut-off frequency is entered during filtering
Detail	The cut-off frequency entered for the filtering processing is an abnormal value
Action	1) Back up all the files in the controller and send them to us.

Code	E32760 Abnormal sampling time is entered during filtering
Detail	The distance compensated in the up or down direction exceeded the up / down trajectory deviation limit distance.
Action	1) Check if the workpiece position is normal. 2) If the work position is normal, check if the arc sensing trajectory deviates from the welding line. 3) If there is a deviation from the welding line, check if the arc sensing parameters (data delay time, maximum compensation distance per second, etc.) are normal. 4) If the arc sensing parameter is normal, check if the data input for sensing is normal. 5) If there is no problem with the above items, increase the left / right trajectory deviation limit distance.

5.2. Warning

Code	W32751 There is no data delay mode for the current welding mode and number.
Detail	There is no data delay for the synergic mode or program number of welding condition.
Action	1) Use a welding condition according to the synergic mode or program number defined with the data delay. 2) To use the current welding condition, reset the data delay mode accordingly.

Code	W32752 The weaving frequency is lower than the minimum range of data delay table.
Detail	The used weaving frequency is lower than the minimum weaving frequency value set in the data delay and following coefficient table.
Action	1) Set bigger weaving frequency than the minimum value.

Code	W32753 Weaving frequency table error: One input value is 0.
Detail	Abnormal 0 is entered among the entries of the weaving frequency table.
Action	1) Sort the weaving frequency entries of data delay and following the coefficient table in ascending order, except for those with 0. 2) Arrange 0 entries at the back.

Code	W32754 Weaving frequency table error: Not in ascending order
Detail	Entries are not in the ascending order in the weaving frequency table.
Action	1) Sort the entries in the weaving frequency table in ascending order.

Code	W32755 Data delay is out of the normal range.
Detail	Data delay exceeds the allowed range for the weaving frequency.
Action	1) Enter data delay, which is lower than 1.25 times of one cycle, for the weaving frequency.

Code	W32756 Arc sensing current exceeded the normal range above the abnormality determination time.

Detail	Arc sensing input data are unstable so it exceeded the normal range above the abnormality determination time.
Action	1) Check if correct sensing data is inputted for welding. 2) If the sensing data is normal, set large abnormality determination margin and time.

Code	W32757 The filter of the robot applied to the weaving section is abnormal.
Detail	The filter applied to the weaving section does not match the setting.
Action	1) Check if the F1, F2, and Fc filter values of all axes are the same in the robot servo parameters. 2) If there is no problem, back up the files in the controller and send them to us.

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